APPENDIX 8. SOME PROCEDURES FOR RADAR ANTENNA VERTICAL PATTERN MEASUREMENT BY SOLAR MEANS

1. GENERAL. FMO's ordinarily do not perform "solar" antenna measurements (see paragraph 1601 g. of this order). When such measurements are done, the procedures described below are suggested. There are several procedures, but all have the same purpose.

a. The methods described in this chapter use the sun's electromagnetic radiant "noise" as a signal source. Measurement is accomplished with an FSM or SA in either a manual or computer-controlled recording system and recorders of either pen type or floppy disc. This system also requires shutdown of the radar, since the radar antenna is connected to the measurement system. The antenna is left at its normal mechanical tilt and rotated at its normal speed, with the transmitter and receiver turned off. These "solar" procedures described below are examples of some of the available and effective procedures.

b. As the earth rotates, the sun "rises" above (or "sets" into) the horizon, and it effectively passes through the radar antenna's main beam. That relatively stable noise source is recorded at each revolution. Since the radar's rotation is very rapid with respect to the angular velocity of the sun, many antenna revolution sun passes are possible at approximately the same elevation, thus enabling the recording system to average out small differences and give a very high degree of resolution.

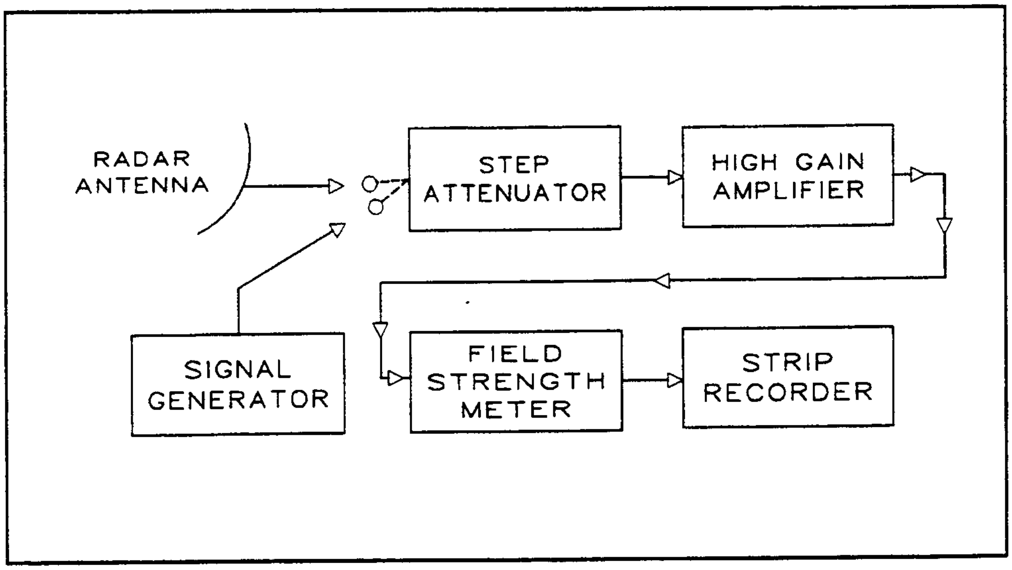
c. The RFIM van is equipped to make horizontal radar antenna pattern measurements. The van equipment may be used by the FMO for the vertical pattern measurements described in this appendix. Some additional equipment may be needed depending on which method of measurement is used.

d. There is considerable equipment setup and calibration required which, instead of being in the van, must be transported to the radar site, set up, taken down, then the results either manually plotted or fed into an automatic plotter back at the FMO's office.

2. TWO METHODS OF SOLAR MEASUREMENTS. Two methods of solar-based radar antenna pattern measurement are manual and automated. Each will produce quality results, but the automated method does away with any manual extrapolation, interpolation, and plotting. It produces a superior product at the expense of using a computer and considerable other equipment.

3. MANUAL MEASUREMENT. A vertical antenna pattern can be produced manually from just the NM-65T field strength meter, an attenuator, an amplifier, and a strip chart recorder. The recorded signal will be the signal received from the sun's noise radiation as the antenna sweeps past the sun's azimuth. A block diagram of the necessary equipment setup is found in figure 1, with a procedural description following.

FIGURE 1. BLOCK DIAGRAM OF MANUAL MEASUREMENT



a. Equipment required for a radar antenna measurement using the sun as a source is essentially the same as the setup in the RFIM van. However, the relatively weaker source (sun noise) requires extra amplification and a source of accurate time is needed.

(1) Any good high-gain amplifier with a low noise figure may be used. The AVENTEK AMG 2021 or 2022 for 1-2 GHz or the AMG 4031 for 2-4 GHz are examples.

(2) An accurate field strength meter. The Eaton NM-65T FSM supplied the FMO's is excellent. The later model NM-67T is also excellent for those who have it. The signal output of a quality spectrum analyzer could also be used in lieu of the FSM.

(3) An in-line step attenuator, with at least 30 dB total attenuation, in steps of 1 or 2 dB is required.

(4) A strip chart recorder is needed. This is a key element in the measuring package. It must have low ballistics so that it follows the detected noise signal accurately; e.g., 10 msec or less from zero to full scale. It also must be capable of quite slow paper travel to permit recording the passes in a reasonable length of paper. An HP 17401A recorder has been used satisfactorily, but this is a two channel device and requires considerable adjustment to get the crossover of the two channels to match. There are several strip chart recorders available which will do the job satisfactorily. The principal concern is that it have sufficient span to accurately record a 25-30 dB range of values and that it is capable of being set to a slow speed of around 5 millimeters per minute (mm/min).

(5) A time source accurate to a few seconds a day is required. Before using the time source, it should be coordinated with an accurate time source such as radio station WWV. If a time-tick device is available, that device can be used to put a marked tick on the recording automatically. If not, a manual mark each minute will be sufficient.

(6) An accurate determination of the sun's position is essential. The sun's position with respect to time, date, and geographical position of the radar must be accurately known, otherwise the whole measurement will be faulty. The radar's coordinates can be obtained from the IRAC authorization document, GMF files or GPS receiver. The sun's actual position minute-to-minute is determined from the Air Almanac or Nautical Almanac, published by the Naval Observatory, Washington, DC.

b. Measurement procedure.

(1) Connect the system components as shown in figure 1, with the calibrating signal generator connected to the input of the in-line step attenuator.

(2) Set the in-line attenuator to 0 dB.

(3) Set and calibrate the NM-65T to the frequency of the radar.

(4) Set the NM-65T attenuator to the 0 dB position.

(5) Set the NM-65T function.

(a) The function setting is critical to the calibration procedure, thus to the overall accuracy of the measurements. Some experimentation will be necessary and will depend on many factors. Whether field intensity, direct peak, or quasi-peak function is used will depend upon the systems setup, the ballistics of the strip recorder, the radar antenna azimuth rate and the antenna beam width (±3 dB). For instance, an ARSR with a rate of 4 revolutions per minute (r/min) and a beam width of 2° would mean an illumination of the antenna within its beam width for 2/360 x 15 secs = 83.33 msec. That means the strip recorder has only 83 msec to reach its full swing position and come to rest before it starts down again. A 2° beam width of an ASR of 15 r/min would give illumination for only 2/360 x 4 secs = 22.22 msec to accomplish the same swing. Depending on the ballistics of the recorder and the time constant of the FSM, this could be sufficient to give an accurate reading, or could lag behind the actual value due to the "drag" resulting in an inaccurate reading.

(b) Testing of the setup must be done before the first measurement is made. Once done, the parameters will be known and set for all subsequent measurements, using the same equipment and antenna rates. The manufacturer's instruction book should specify the slew rate of the pen. If it will make a full excursion in 20 msec or less, then both the examples in subparagraph b(5)(a) above would be operable in quasi-peak function. However, if as is often the case with recorders which have slow paper rates, the manufacturer specifies the slew rate as 500 msec or so, another function will be required, most likely peak with 0.5 sec hold time.

(c) Peak function in the NM-65T holds the meter reading (and thus the recorder output) for 0.5 or 5 sec, switchable. This is to permit easy reading of a very short pulse, even a µsec or less. Setting the time constant to 0.5 sec would match a 500 msec slew rate of a strip recorder. The NM-65T inserts a brief "dump" voltage (a reverse voltage) at the end of the selected hold time in direct peak function to restore the charging circuit to zero quickly to be ready for the next pulse to be measured. This is satisfactory if the strip recorder is partially damped or has a slow slew rate. Damping allows the pen to return to zero safely, without "ramming" it down and possibly damaging the recorder. The 5 sec peak time constant would be acceptable for an ARSR rate of 4 r/min, but not an ASR of 15 r/min because the next illumination would come before the 5 sec "hold" time had expired.

(d) Quasi-peak in the NM-65T has a time constant of around 10 msec which is ideal for the Techni-rite 711 high-speed recorder used for antenna patterns described in chapter 13 of this order. The TR-711 would be excellent for this solar measurement, except the slowest normal speed would run out quite a bit of paper for the hour or more required for a complete sun "pass." If the TR-711 is reduced in tape speed to be usable for this function, then quasi-peak must be used, or the "dump" feature of direct peak will render the recording useless and could damage the recorder. The TR-711 has a slew rate of approximately 5 msec to full scale and no damping.

(6) Calibrate the strip recorder by injecting a known signal at a level about 150 to 250 milliVolts (mV) and adjusting the recorder scan to a desired scale reading, usually about 75 percent. Experience will soon teach what level is expected to be the peak noise recorded off each type of radar antenna and frequency. The NM-65T will handle a 60 dB dynamic range of level without distortion. Should the recorded level be above scale with the in-line attenuator set at 0, insert sufficient attenuation with this device to bring the pen to an on-scale reading for the whole recording session. DO NOT reduce signal level with the NM-65T internal attenuator. Doing so would activate AGC action within the NM-65T which occurs at other than 0 dB setting and would upset recording linearity. Set the recording paper speed at an appropriate rate, nominally around 5mm/min.

(7) Insert steps of attenuation with the signal generator untouched, (maximum of 2 dB/step) so that the individual levels of attenuation are shown on the recorder paper. After step intervals of 25 to 30 dB attenuation levels have been recorded and marked on the recording strip, return the attenuator to 0 dB.

(8) Disconnect the generator and connect the radar antenna to the input of the attenuator. With the radar turned off, start the antenna rotating.

(9) Sunrise (or sunset) time will have to have been previously determined for the particular day of the measurement. The actual recording should be started 2-3 min before sunrise. If the measurement is to be made at the sunset period, start the recording in sufficient time to assure a full range of vertical azimuth desired. Also start the time ticks and assure they are marked either manually or automatically on the recording for later data resolution.

(10) Run the recording for as long as needed to show the range of vertical pattern desired. For a NADIF, for instance, this is just over an hour. Once the peak has been reached and further sun azimuthal excursion drops the sun noise passes more than 20 to 25 dB from the peak, recording may be stopped.

(11) Rerun the calibration on the recording at this time, to assure that parameters have not drifted significantly. Should they somehow have done so, it will be necessary to check all equipment and the overall system to find the cause of the apparent drift before another recording is made.

(12) Dismantle the setup and disconnect the equipment. The recording is now ready to be analyzed to permit drawing the actual radiation pattern. Refer to figure 2.

c. Data analysis. With the recorded signal in hand, it is now possible to calculate the actual vertical beam pattern. The recorder sheet already has the calibration on it, so the only analysis required is to correlate the sun's azimuth with the time ticks on the recording.

(1) Using the sun's position determined from the Naval Observatory Almanac, mark each fractional degree of sun azimuth on the recording aside the time tick marks. These should be small increments of 0.1° or so.

(2) Using the previous calibration marks, evaluate and mark each azimuth increment with a dB value. Generally, there will be a small variation of ±1 dB or less between successive passes. If so, take a simple average of those passes nearest the marked increment.

(3) Analyzing the calibrated recording, work up a chart of vertical azimuth in degrees versus amplitude in dB. Refer to figure 3.

(4) Using the data now available, plot the chart values onto a graph of expanded angular scale to produce a graphic view of the actual vertical beam antenna pattern of the radar measured. Be sure to subtract any mechanical tilt from the plot, or to specifically indicate that the plot is true vertical azimuth as installed, rather than the actual vertical radiation pattern of the antenna itself.

FIGURE 2. SAMPLE RECORDING WITH CALIBRATION, TIME AND AMPLITUDE MARKINGS

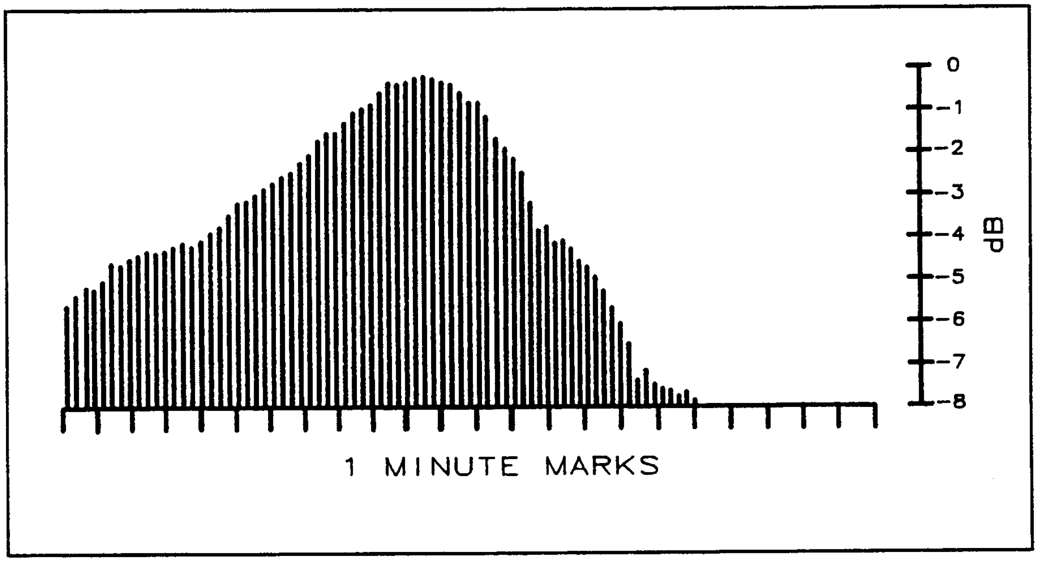


FIGURE 3. SAMPLE PLOT OF ANALYZED RECORDING